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RESEARCH ARTICLE

Notes on early childhood diets in early modern Oulu, Finland, based on the stable isotope case studies of archeological dentin

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Abstract

In mid-18th-century Sweden, the newly enhanced census records revealed higher-than-expected infant mortality rates in certain regions of the kingdom. This convinced contemporary elite men of common women deliberately refusing to breastfeed out of vanity and lack of care. One of the worst regions in terms of infant mortality was the province of Ostrobothnia, located in the area of what is now Finland. To explore the allegations, we measured the carbon ($\delta^{13}C$) and nitrogen ($\delta^{15}N$) stable isotope ratios in the collagen of incremental crown dentin segments of the permanent first molars (M1) of six individuals excavated from the early modern churchyard of the town of Oulu, Ostrobothnia. The results do not directly support the worries over the lack of breastfeeding but imply a variety of related practices in Oulu at the time.

KEYWORDS
breastfeeding, carbon and nitrogen stable isotopes, dentin, early modernity, Finland

1 | INTRODUCTION

Mid-18th-century Swedish state officials became concerned over the higher-than-expected infant mortality rates revealed by the recently enhanced census register system. This prompted scrutiny of breastfeeding practices, which were thought to be hindering population growth (Turpeinen, 1987). Currently, it is well known that breastfeeding offers protection against acute infections and even lays the foundation of lifelong health through participating in the formation and function of the infant's immune system (Hanson, 1998, 1999; Pärnänen, 2021, p. 36; Victora et al., 2016).

In early modern Sweden, practice seemed to show that breastfeeding was a significant factor in infant survival. The customs of infant feeding not only were regionally diverse but also largely dictated the variation of infant mortality between parishes. In areas where breastfeeding was traditionally substituted by artificial feeding, much higher mortality rates prevailed. Some of the worst regions located in the area of what is now Finland, at the time part of Sweden. Many parishes in the province of Ostrobothnia experienced horrendously high rates. The elite soon agreed that the perceived careless unwillingness of common women to breastfeed was a serious state political problem, causing the labor and military forces severe losses in the form of child mortality (Brändström, 1984; Halila, 1954, pp. 639–640; Turpeinen, 1987).

But did the early modern mothers of Ostrobothnia indeed not breastfeed? To preliminarily look for support for these allegations, we measured the carbon ($\delta^{13}C$) and nitrogen ($\delta^{15}N$) stable isotope ratios in the collagen of incrementally cut crown dentin segments (1 mm) of the permanent first molars (M1) of six individuals. These isotope ratios can be analyzed to conclude whether they signal consumption of human breastmilk during dentin development in infancy (Tsutaya & Yoneda, 2015). Their remains of the studied individuals were

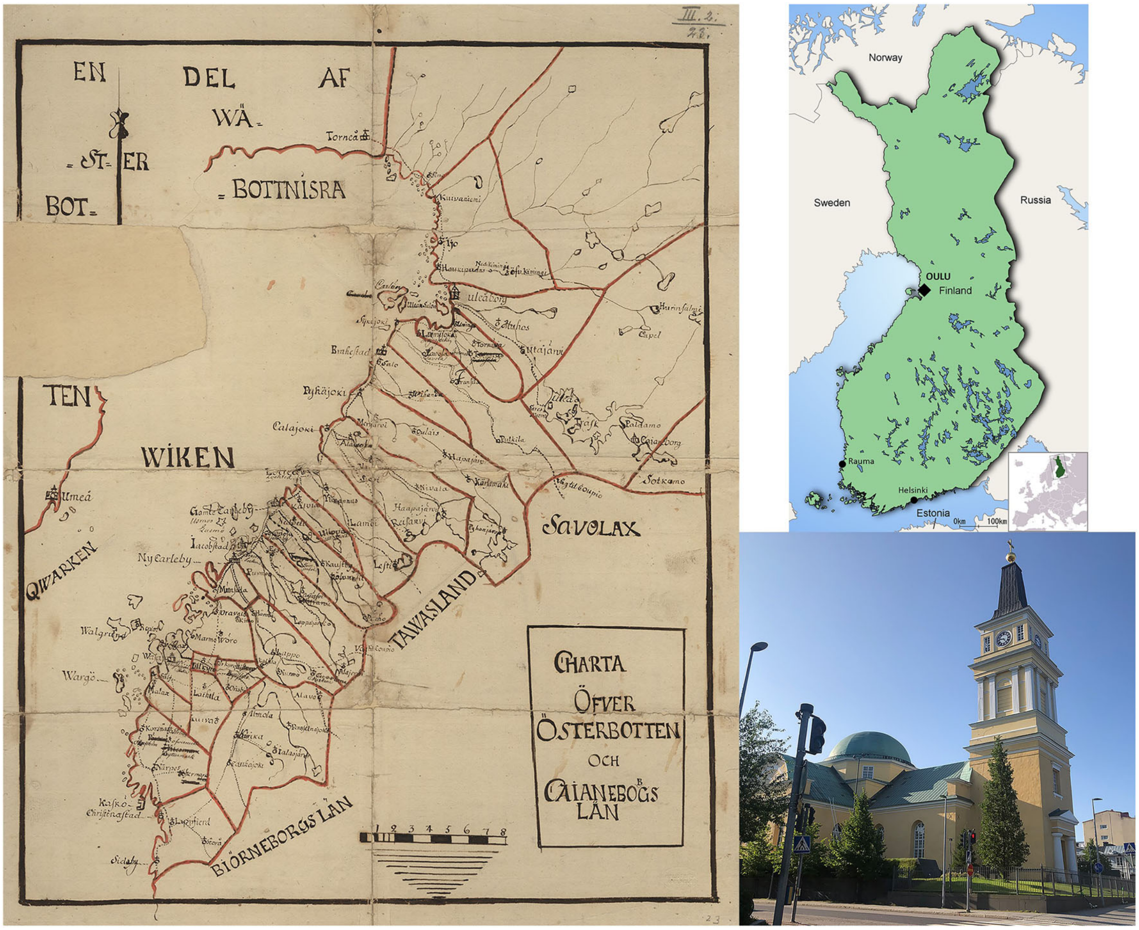

FIGURE 1 The current nation state of Finland was part of Sweden until 1809. The historical map from the 18th century depicts the approximate historical borders of the vast province of Ostrobothnia along the Bothnian Bay and the location of Oulu (Uleåborg). Oulu Cathedral, surrounded by the former burial ground, was originally constructed in 1777. In 1822, its wooden structures were damaged in a fire and needed to be rebuilt. In 1845, the renovation according to the design of architect Carl Ludwig Engel was completed. Image: S. Lipkin. Charta öfver Österbotten och Caianebo[r]gs län, National Library of Finland (public domain: https://urn.fi/URN:NBN:fi-fe201010112572). Modern map: public domain, Wikimedia Commons [Colour figure can be viewed at wileyonlinelibrary.com]

excavated from the 17th- to 18th-century churchyard of Oulu (Ostrobothnia, Finland; Figure 1).

2 | MATERIALS AND METHODS

Oulu, at latitude 65° North, is the fifth largest city in Finland (Figure 1). The studied skeletal human remains were excavated in connection with the 1996 and 2002 large-scale renovations of the town's historical churchyard. The work was governed by the city parish also authorizing the study of these remains. Since at least the 1610s, soon after the town was founded in 1605, its churches and the burial ground have been located in or near this plot. The old burial ground surrounds the current city cathedral (Figure 1), some of its area extending under the later-built streets and buildings. The constant use of the same restricted area for burials for well over a century destroyed the oldest graves. Thus, determining the *terminus post quem* of the analyzed skeletal remains is not possible, whereas the establishment of the new cemetery in 1780 marks the *terminus ante quem* (Kallio-Seppä & Tranberg, 2021).

The currently stored skeletal material from the excavations consists of mandibles. Two were from unknown primary burial contexts, and more precise dating was not attempted. Due to the general lack of preserved diagnostic skeletal regions relevant for age and sex estimation, precise ages or biological sexes were not assigned to the studied individuals. All individuals were defined as adults based on their fully erupted wisdom teeth. Given this, and the *terminus ante quem* of the burials, the infancy of these individuals dates prior to c. 1760, which sets the temporal upper limits for the breastfeeding practices this study can be utilized to observe.

Late 17th- to early 18th-century Oulu was inhabited by both rich merchants and low-income families. The border between urban and rural was still obscure, and living was influenced by the sea and the Oulujoki river running through the town. The large catches of salmon from the rivers of the northern coastal regions of Ostrobothnia were important in Oulu. Their export was managed by the town merchants

TABLE 1 Stable isotope results of incrementally sampled M1 dentin from the occlusal surface toward the root

Individual	DEJ–CEJ (max)	M1 (mm)	Age (end of development)	$\delta^{13}C$ (‰)	$\delta^{15}N$ (‰)	C%	N%	C/N atom
OTK-02 VIb Surv. K39	5 mm	0–1	0.6	−20.7	13.3	42.96	15.51	3.2
		1–2	1.1	−20.7	13.2	43.64	15.77	3.2
		2–3	1.7	Sample destroyed before analysis				
		3–4	2.3	−20.3	13.1	45.52	16.49	3.2
		4–5	2.8	−19.7	13.6	44.86	16.13	3.2
		5–6	3.4	−19.9	13.2	42.99	15.45	3.2
		6–7	4.4	−20.2	12.4	42.46	15.28	3.2
		7–8		−20.2	12.2	45.98	16.41	3.3
		8–9	5.5	−20.3	12.1	41.44	14.92	3.2
		9–10		−20.5	11.8	44.31	16.02	3.2
		M3	Teen	−20.5	10.6	39.42	14.73	3.1
		Bone	Adult	−20.3	11.8	42.45	15.45	3.2
OTK-02 VIb P18 H42		2–3	1.7	−21.0	10.8	40.23	14.32	3.3
		3–4	2.3	−20.8	11.5	44.60	16.00	3.3
		4–5	2.8	−20.6	11.8	45.52	16.39	3.2
		5–6	3.4	−20.3	11.8	42.60	15.28	3.3
		6–7	4.4	−20.4	11.7	41.98	15.10	3.2
		7–8		−20.4	12.0	44.17	15.89	3.2
		8–9	5.5	−20.3	12.2	43.33	15.68	3.2
		9–10		−20.2	12.3	42.12	15.22	3.2
		M3	Teen	−20.3	11.7	39.84	14.49	3.2
		Bone	Adult	−20.2	12.3	44.05	16.20	3.2
OTK-96 Os. 3 K60	5.5 mm	0–1	0.6	−20.1	14.5	45.16	16.56	3.2
		1–2	1.1	−20.1	12.8	45.54	16.70	3.2
		2–3	1.7	−20.4	12.2	46.14	16.90	3.2
		3–4	2.3	−20.4	12.3	44.77	16.41	3.2
		4–5	2.8	−20.5	12.4	45.86	16.77	3.2
		5–6	3.4	−20.4	12.4	46.83	17.27	3.2
		PM2	Mid-childhood	−21.0	12.5	37.00	13.81	3.2
		M3	Teen	−21.0	11.8	39.35	14.27	3.2
		Bone	Adult	−21.0	11.6	43.05	15.75	3.2
OTK-02 VIb H29	6 mm	0–1	0.6	−19.9	15.2	40.17	14.48	3.2
		1–2	1.1	−19.9	14.6	40.41	14.50	3.3
		2–3	1.7	−20.1	11.8	40.27	14.52	3.2
		3–4	2.3	−20.1	12.1	41.41	15.12	3.2
		4–5	2.8	−20.0	12.4	43.94	15.81	3.2
		5–6	3.4	−20.0	12.5	20.65[a]	7.36[a]	3.3
		6–7	4.4	−20.0	12.6	44.96	16.09	3.3
		7–8		−19.8	12.8	45.19	16.33	3.2
		8–9	5.5	−19.7	13.1	43.88	15.80	3.2
		9–10		−19.7	13.2	44.70	16.11	3.2
		PM2	Mid-childhood	−19.9	11.8	39.33	14.24	3.2
		M3	Teen	−20.8	10.9	40.26	14.59	3.2
		Bone	Adult	−20.7	11.5	41.60	15.02	3.2

(Continues)

TABLE 1 (Continued)

Individual	DEJ–CEJ (max)	M1 (mm)	Age (end of development)	δ^{13}C (‰)	δ^{15}N (‰)	C%	N%	C/N atom
OTK-02 IIa Chamb. K16		0–1	0.6	−20.5	13.6	41.41	15.12	3.2
		1–2	1.1	−20.7	13.3	39.39	14.26	3.2
		2–3	1.7	−20.9	13.0	39.48	14.18	3.2
		3–4	2.3	−21.1	12.3	39.21	14.04	3.3
		4–5	2.8	−20.9	12.1	39.40	14.26	3.2
		5–6	3.4	−20.6	12.7	43.31	15.59	3.2
		6–7	4.4	−20.5	12.7	43.24	15.68	3.2
		7–8		−20.4	12.7	43.01	15.59	3.2
		8–9	5.5	−20.3	12.9	43.11	15.58	3.2
		9–10		−20.2	13.0	43.03	15.57	3.2
		M2	Mid-childhood	−20.6	11.8	37.06	13.41	3.2
		M3	Teen	−20.8	11.8	39.57	14.42	3.2
		Bone	Adult	−20.8	11.9	43.10	15.55	3.2
OTK-02 G01 K42		0–1	0.6	−19.9	15.1	44.46	16.03	3.2
		1–2	1.1	−20.1	14.7	43.82	15.83	3.2
		2–3	1.7	−20.6	13.8	43.68	15.88	3.2
		3–4	2.3	−21.1	12.5	43.91	15.86	3.2
		4–5	2.8	−21.1	11.7	44.22	15.99	3.2
		5–6	3.4	−21.1	12.1	43.31	15.65	3.2
		6–7	4.4	−21.1	11.3	45.11	16.26	3.2
		7–8		−21.0	11.6	42.74	15.47	3.2
		8–9	5.5	−21.0	12.2	43.93	15.60	3.3
		PM2	Mid-childhood	−20.7	11.7	36.73	13.36	3.2
		M3	Teen	−20.6	11.6	38.80	14.43	3.1
		Bone	Adult	−20.6	11.9	40.70	14.88	3.2

Note: The age estimations are modified after Eerkens et al. (2011), and the end of the development of each segment is marked. The data representing mid-childhood, teens, and adulthood have been previously published in Väre, Arppe, et al. (2022). The distance between DEJ (cusp) and CEJ is presented when possible.

Abbreviations: CEJ, cementoenamel junction; DEJ, dentin–enamel junction.

[a]Collagen quality control analysis failure.

enjoying the borough rights and exploiting the sea connections to larger Swedish towns. Animal husbandry was an important profession in the region, and game was hunted. Crops were cultivated, although the yield remained low, with repeated harvest failures necessitating importation (Halila, 1954; Satokangas, 1987; Vahtola, 1987). The 17th century ending with one of the worst hunger catastrophes recorded in Finland (1695–1697) was particularly difficult, as the average temperatures dropped to a record low (Luoto, 2013). The rather high levels of the δ^{15}N values obtained in a previous study of the population agree with this prior understanding concerning diets in early modern Oulu (Väre, Arppe, et al., 2022). Although the climate conditions eased and the agricultural yield slowly increased during the next century, its early decades were shadowed by the Great Wrath (1714–1721), the time of Russian occupation of Finland during the Great Northern War (1700–1721). The population decreased during these periods due to famine and persecution, but the losses were quickly made up and the century was generally marked by economic growth. With its population of ~2000 inhabitants, Oulu became the second largest town in Finland after the contemporary capital, Turku (Satokangas, 1987; Vahtola, 1987).

The method is based on isotopic fractionation of the heavier and lighter nitrogen and carbon atoms. It causes trophic enrichment of the heavier isotopes in tissues of breastfed infants, who are above their nursing mothers in the food chain (Fogel et al., 1989; Fuller et al., 2006). The M1 crown develops during the first 3 to 4 years (AlQahtani et al., 2010), which typically include the breastfeeding period for humans as a mammal species, although longer periods are possible. The isotope composition of its collagen reflects the protein intake during its formation (Ambrose & Norr, 1993; Fernandes et al., 2012). Exclusive breastfeeding during the first months causes especially the δ^{15}N and to a lesser degree the δ^{13}C values to elevate in the concurrently forming M1 dentin beginning at the dentin–enamel junction. In dentin formed during the following months, when weaning begins, these values decline until they stabilize near maternal level when breastfeeding ends. Thus, comparing the values in the incrementally grown dentin segments of 1 mm allows dietary changes such as those resulting from breastfeeding and weaning to be traced (e.g., Beaumont et al., 2013; Eerkens et al., 2011).

A trophic level difference of ∼3.4‰ in δ^{15}N values is observed between producer/prey and predatory species (Minagawa & Wada, 1984). The typical elevation in tissues of exclusively breastfed infants in comparison to the maternal value is smaller, ranging between ∼2‰ and 3‰ (Fogel et al., 1989; Fuller et al., 2006), although even smaller intervals have been observed (Herrscher et al., 2017). The δ^{13}C value elevation is usually ∼1‰. As it is impossible to study the tissues of the subjects' own mothers, the average values of the studied individuals' own second premolar and third molar (root below cementoenamel junction [CEJ]) and bone collagen ($n = 17$: δ^{13}C $= -20.6$‰ ± 0.3; δ^{15}N $= 11.7$‰ ± 0.4, respectively; Väre, Arppe, et al., 2022; Table 1 and Figures 2–7) are used as the proxy for maternal values with the assumption that families consumed similar nutrition. These proxies represent the level at which the δ^{13}C and δ^{15}N values in dentin segments formed after breastfeeding was no longer being practiced are expected to decline. The true maternal values may have varied substantially. Thus, it should be considered that the values may not compare as hypothetically expected, and interpreting the pattern they form across the set of dentin samples is important.

Previously, it has been estimated that each 1 mm segment develops within approximately 6 months. This can be calculated assuming that the M1 crown completion takes ∼3.5 years from birth (AlQahtani et al., 2010) and the average of mandibular M1 crown height is 6.74 + 0.93 mm (Ngeow et al., 2020). The temporal resolution of the growth in segments adjacent to the dentin–enamel junction is rather high, but due to the dentin growth pattern, in sections toward the apex, the different segments increasingly temporally overlap, which blurs the chronology of the changes (Beaumont et al., 2018; Beaumont & Montgomery, 2016; Eerkens et al., 2011; Tsutaya, 2020). Thus, a maximum of 10 sections counting from the occlusal surface were analyzed. The age estimations for particularly the last segments are rather arbitrary.

The wear of M1 enamel was slight, implying the relatively young age of most of the subjects. Age and dental wear are interconnected and significant factors in consideration of the representativity of dentin samples. The metabolically inert primary dentin preserves the dietary information from its developmental period (Hillson, 1996), but destruction of the occlusal dentin, more typical in older individuals, obliterates the tissue formed during the first months of life. In addition, the isotope composition of teeth may be compromised by secondary dentin forming around the pulp chamber later in life, representing the conditions of that period (Meinl et al., 2007; Smith et al., 2012). Caries, wear, and traumas induce tertiary dentin formation, but this is distinguishable by its brownish color. Any clearly discolored dentin and carious tissue was removed during sample preparation to inhibit time-averaging effects or chemical anomalies (wear/discoloration: H42; caries at CEJ: K16).

The collagen extraction during sample preparation was conducted at the laboratory facilities of the Faculty of Medicine, University of Oulu, by the first author according to the protocol described by Beaumont et al. (2013). The vertical halves of teeth brushed free of macroscopic debris and bisected using a diamond wheel cutter were ultrasonicated in ultrapure water (Milli-Q). Detachable enamel was removed, and the teeth were demineralized in 0.5 M hydrochloric acid (HCl) at room temperature for 1 to 2 weeks. The demineralized teeth

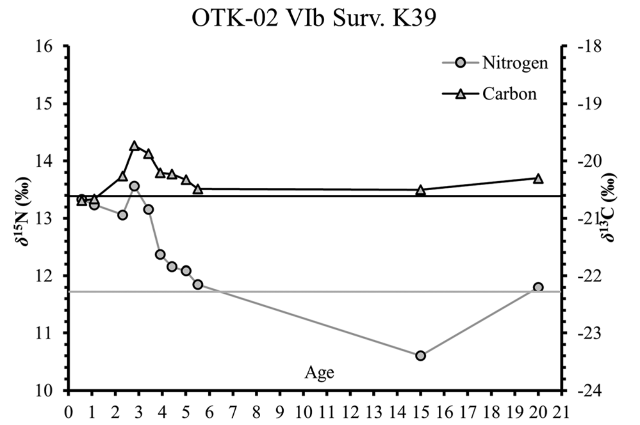

FIGURE 2 The elevation of the δ^{15}N value in the first segment is not very high relative to the maternal proxy (+1.7‰), and the pattern of values is not typical for M1 dentin of breastfed infants, although the missing third value interferes with the interpretation. Although it is possible this individual was never exclusive breastfed, supplementary breastmilk could have been provided. The elevation of values in dentine developed during the third year probably results from some unrelated factor. The values representing mid-childhood are missing, but the teenage diet may have contained larger amounts of plant nutrition, whereas the diet in adulthood was more like that typically consumed by the studied individuals after early childhood (as indicated by the average lines representing the maternal proxies).

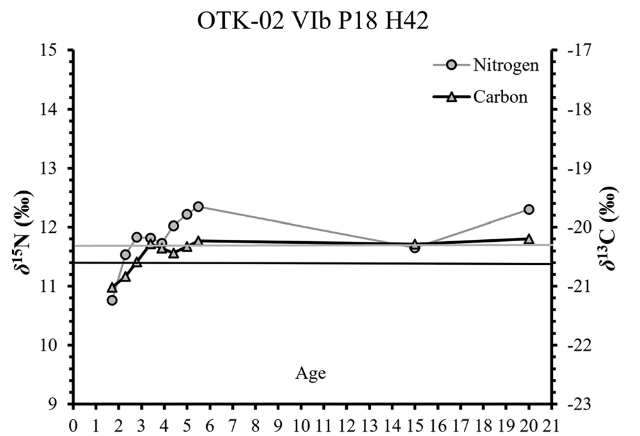

FIGURE 3 Due to wear of the occlusal dentin, no information concerning the diet of the first year is available. Both the δ^{13}C and δ^{15}N values in the third section are low (δ^{15}N: −0.9‰ vs. maternal proxy), which indicates that this individual did not receive breastmilk after turning 1. The diet of early childhood but after infancy contained increasing amounts of heavy nitrogen isotopes for unrelated reasons. The values representing mid-childhood are missing, but the diet during youth resembled the average diets consumed by the rest of the studied individuals after early childhood. The adulthood diet maybe again included more foods enriched with ^{15}N atoms.

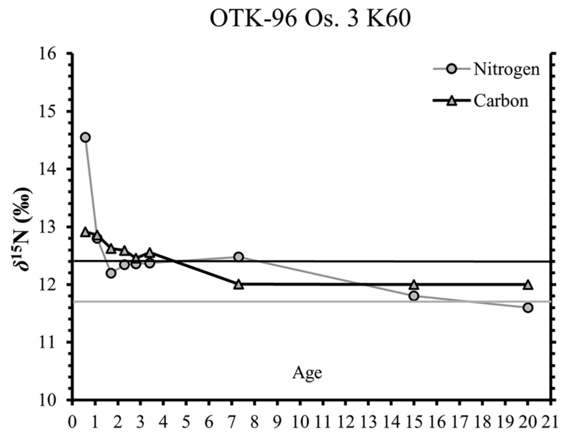

FIGURE 4 The elevated $\delta^{15}N$ value (+2.8‰ vs. maternal proxy) of the first segment implies exclusive breastfeeding for the first 6 months. In addition, the $\delta^{13}C$ values decline slightly as a function of time, supporting the interpretation. The $\delta^{15}N$ values stabilize near the population mean in the third segment beginning to develop soon after the first birthday, which is probably a sign of breastfeeding having ceased by then. Judging by the rather sharp decline early on, weaning was likely started rather intensively after the first 6 months. Although the mid-childhood diet of this individual included relatively more ^{15}N-containing foods than the average diets of the studied individuals, after early childhood, their later diets are more like the averages.

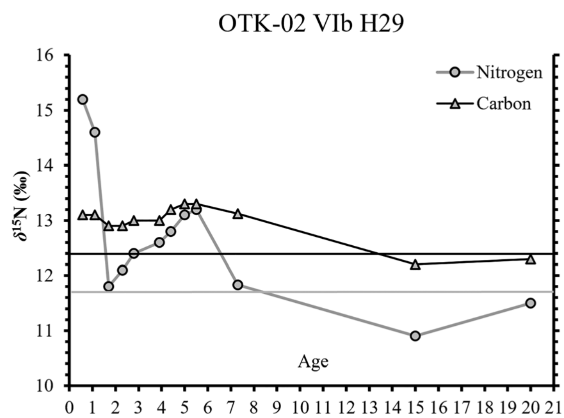

FIGURE 5 The elevated $\delta^{15}N$ value (+3.5‰ vs. maternal proxy) of the first segment implies exclusive breastfeeding for the first 6 months. The $\delta^{15}N$ values reach the population mean in the third segment, developing after turning 1 year of age, which is when breastfeeding probably had ceased. The re-elevation of the $\delta^{15}N$ values in the later period forming dentin increments is due to other factors affecting the diet. The $\delta^{13}C$ values stay rather constant throughout childhood. The diet during youth may have contained more plant foods—also in comparison to the average diets consumed by the rest of studied individuals after early childhood.

were rinsed with ultrapure water and sliced with a surgical scalpel in parallel horizontal sections of 1 mm, beginning from the crown and proceeding toward the root. The dentin sections were placed in microcentrifuge tubes (Eppendorf) and gelatinized in a pH 3 (0.001 M) HCl solution at 70°C for 24 h, after which the samples were centrifuged, frozen, and lyophilized.

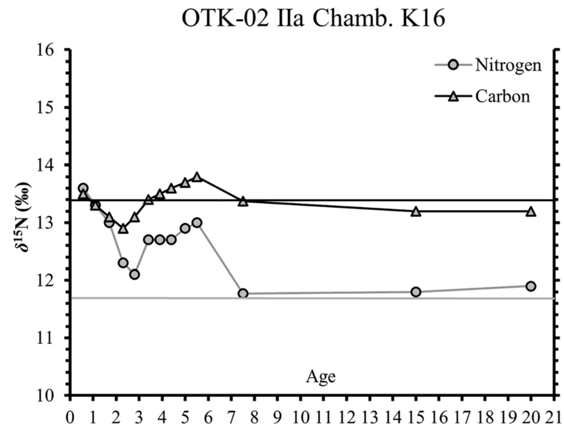

FIGURE 6 In comparison to the maternal proxy, the elevation of the $\delta^{15}N$ value in first segments is rather slight (+1.9‰). This most likely implies lower ^{15}N content in the maternal diet, as the pattern values point toward breastfeeding, which after being exclusively practiced for 6 months may have continued beyond the second birthday, as the $\delta^{15}N$ values only decline close to the population level in the fifth section. The postweaning diet probably included abundantly foods enriched in heavier isotopes (aquatic species), whereas the later values resemble the rest of the group.

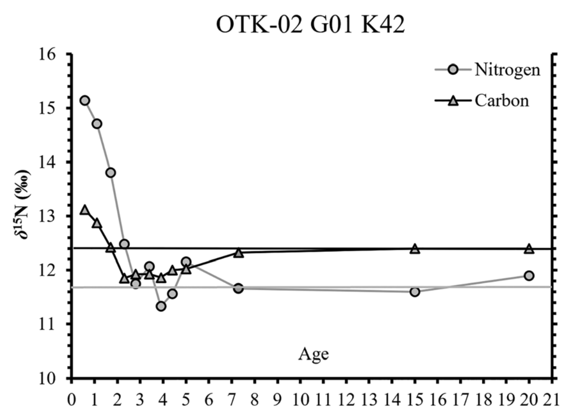

FIGURE 7 The elevated $\delta^{15}N$ value (+3.4‰ vs. maternal proxy) of the first segment implies full breastfeeding for the first 6 months. The $\delta^{15}N$ values decline at the population level in the fifth segment, beginning to develop sometime after the second birthday. This may imply gradual weaning until this. The $\delta^{13}C$ values declining simultaneously during the first years support the interpretation. The later drop of the $\delta^{15}N$ values (−0.9‰ vs. the population mean) is likely due to other factors unrelated to breastfeeding. Diet after early childhood is consistent with the averages of the same period of the rest of the group.

The analyses were conducted at the Nuclear Research Department, Center for Physical Sciences and Technology, Vilnius, Lithuania, using a FlashEA 1112 Series Elemental Analyzer connected to a Delta V Advantage Isotope Ratio Mass Spectrometer (IRMS) via a ConFlo III interface (all Thermo, Bremen, Germany). The elemental analyzer consists of oxidation and reduction furnaces (operating at 1020°C and 650°C, respectively), a chromatographic column (PoraPlot Q), water absorption column, and TCD detector. During the analysis, N% and C

% were determined using the elemental analyzer. Gasses were passed to the IRMS for stable isotope ratio measurement. The isotopic ratios for nitrogen ($^{15}N/^{14}N$) and carbon ($^{13}C/^{12}C$) are expressed relative to the international standards ($\delta^{15}N$ AIR ‰ and $\delta^{13}C$ VPDB ‰) with the δ notation as parts per thousand. Caffeine IAEA-600 ($\delta^{15}N = +1$‰; $\delta^{13}C = -27.77$‰), USGS24 ($\delta^{13}C = -16.05$‰), and IAEA-NO-3 ($\delta^{15}N = +4.7$‰) were used as secondary reference materials; the analytical precision for both values is 0.1‰.

3 | RESULTS

The $\delta^{13}C_{dentin}$ and $\delta^{15}N_{dentin}$ values were analyzed in 52 segments of 6 individuals of which 51 passed the following quality control (Table 1). The atomic C:N ratios were between 3.0 and 3.3, which is in line with the newly refined range of 3.00–3.28 for modern collagen of mammals, implying good quality (Guiry & Szpak, 2020). The weight % of carbon between 39.21% and 46.83% and nitrogen between 14.04% and 17.27% were within the previously published ranges (cf. Ambrose, 1990; van Klinken, 1999) and accepted for further discussion. Overall, the $\delta^{13}C$ values are consistent with the brackish/terrestrial C_3 environment the populations inhabited, presumably lacking C_4/marine influences, and also exhibited little variation (-20.4‰ ± 0.4; -21.1–[-19.7]‰). The $\delta^{15}N$ values were at a quite elevated level (12.7‰ ± 0.9; 10.8–15.2‰; first segments $n = 5$, 14.3‰ ± 0.9; 13.3–15.2‰), as to be expected considering the previous stable isotope study of the population yielding rather high values (Väre, Arppe, et al., 2022).

In Figures 2–7, the age estimations (after Eerkens et al., 2011) at the end of the development of each vertically millimeter-wide sample, beginning from the top of the crown, are plotted on the horizontal axis left to right. Both $\delta^{13}C$ and $\delta^{15}N$ values representing averages of the diet during the development of the segments are plotted on the vertical axis. The averages of the values of PM2 and M3 dentin and bone collagen (formed during mid-childhood, teenage, and adulthood, respectively) of the studied individuals were used as proxies for the maternal values ($n = 17$: $\delta^{13}C = -20.6$‰ ± 0.3; $\delta^{15}N = 11.7$‰ ± 0.4; Väre, Arppe, et al., 2022). These maternal proxies are presented as horizontal lines in the figures (black: $\delta^{13}C$; gray: $\delta^{15}N$). The individual PM2/M3/bone values are additionally presented in Table 1 and plotted in the figures. The M3 or bone collagen of every individual does not represent the diet at the ages designated for the figures, but 15 and 20 years were used for practical reasons.

4 | DISCUSSIONS

The vague pattern formed by the $\delta^{13}C_{dentin}$ and $\delta^{15}N_{dentin}$ values across the set suggests that individual K39 (Figure 2) may never have been exclusively breastfed (Figure 2 and Table 1). Even the $\delta^{15}N$ value in the first segment in comparison to the maternal proxy is not strongly elevated (+1.7‰), whereas at 13.3‰, it is still relatively high. This may imply a much shorter exclusive breastfeeding period than the currently recommended 6 months and/or only supplementary breastfeeding having taken place. The relative scarcity of protein sources in diet during youth may be relevant in connection to the obscurity of the value pattern in infancy. However, in early modern Oulu, high ^{15}N content foods such as fish were easily obtainable, and their presence in diet should not be used as an indicator of high status or wealth in this context.

The dentin segments of H42 developed during the first year could not be analyzed, but the values of the later-forming dentin did not indicate consumption of breastmilk: The $\delta^{15}N$ value in the third segment was -0.9‰ lower than the maternal proxy (Figure 3). Thus, if this individual ever received breastmilk, it happened before the third segment started to form a little after the first year. The values only elevate after infancy, perhaps indicating strong aquatic input, which is also the case with the adult diet. This is unsurprising considering the context. This re-elevation of values experienced by several study subjects after weaning period may imply some common childhood dietary practice in Oulu at the time.

Two individuals—K60 and H29—show signs of abrupt weaning by approximately the age of 1 after initial exclusive breastfeeding for the early half of the first year (Figures 4 and 5). The diet of the later life of K60 seems to align well with the group averages, whereas the mid-childhood diet may have contained more ^{15}N-enriched dishes. The same may be true for the postweaning diet of H29, but during youth, the protein sources of this individual may have been relatively restricted albeit nutritionally sufficient.

On the other hand, implications of rather long breastfeeding periods were observed. In the cases of K16 and K42, after approximately half a year of exclusive breastfeeding, supplementary breastfeeding may have continued beyond the second birthday (Figures 6 and 7). For both these individuals, the values after early childhood resembled the averages in this sample. However, the values measured in dentin segments of K16 developed during the postweaning period were rather elevated, which is interesting considering that the values of the mother (or wet nurse) of this individual were probably rather low. Had the breastfeeding mother consumed a different diet than her toddler after weaning?

No clear indications of the so-called famine pattern characterized by the simultaneously elevating $\delta^{15}N$ and declining $\delta^{13}C$ values are present despite the region having experienced crop failures during the use of the churchyard. Such pattern is thought to result from nutritional stress (Beaumont & Montgomery, 2016) causing tissue catabolism and use of body lipids as energy source leading to the described isotopic changes in growing tissues. Carbon values, however, have been observed to either increase or decrease under nutritional stress (Doi et al., 2017; Mekota et al., 2006; Neuberger et al., 2013).

The results do not straightforwardly support the allegations of the officials accusing the common women of Ostrobothnia of refusing to breastfeed (Turpeinen, 1987). They however indicate that breastfeeding and weaning practices in late 17th- to early 18th-century Oulu may have been more versatile than those in late 18th- to early 19th-century Rauma, Southwestern Finland, supporting the notions of regional diversity of breastfeeding practices (Turpeinen, 1987). In Rauma, exclusive breastfeeding for the first 6 months followed by weaning until nearly 2 years of age may have been common, as the pattern in all seven studied M1s implied this (Väre, Harris, et al., 2022). Such a schedule is well in line with modern recommendations (World Health Organization [WHO], 2015). In Oulu, of those individuals for whom the diet of the first year could be studied ($n = 5$), a period of exclusive breastfeeding was evident for all but one. Even this individual probably received at least supplementary meals of breastmilk. For half, breastfeeding ended after the first year, which is less than the currently recommended minimum of 2 years but would not have contributed to infant mortality (under 1 year). What is more, two of the individuals had likely been supplementarily breastfed even beyond the recommended age.

In four of six cases, the breastfeeding period diverged from the ideal. However, rather than personal choices, the prevailing norms, regulations, necessities, and obligations shaped infant feeding practices (Hadley et al., 2010; Howcroft, 2013). Breastfeeding is time consuming, which is why non-existent or short maternal leave and inflexible working schedules easily disturb it (Taha et al., 2021). Summers in many rural areas of early modern Ostrobothnia were stressful for new mothers, who often needed to return to work mere days postpartum—and to care for the homestead, whereas the men spent weeks on hunting and fishing trips to supplement the livelihood. Often, small children were left in the care of family members who were no longer eligible for work. The breast was replaced with a feeding horn filled with unheated animal milk (Halila, 1954, p. 640; Turpeinen, 1987). So instead of unwillingness, a more likely reason was the general hardships of the everyday life of contemporary mothers. Even when breastfeeding was practiced, the sanitation conditions were not at the modern level in Nordic countries, which aided the spread of many infectious diseases (Turpeinen, 1987).

5 | LIMITATIONS OF THE STUDY

The breastfeeding profiles of such a small group cannot be considered representative of more than a century of family life in Oulu. However, finding evidence of insufficient breastfeeding practices in a diminutive sample consisting of adults is interesting. The studied individuals had survived through childhood, which makes the sample biased, considering that being denied breastmilk during early years forms a possibly fatal health risk (cf. Currier & Widness, 2018; WHO, 2015; Wood et al., 1992). In Ostrobothnia, gastrointestinal conditions, against which breastfeeding is an effective remedy (Hanson, 1999), substantially contributed to contemporary infant mortality (Turpeinen, 1987). A study analyzing the dentin of individuals who died during childhood could reveal a much more significant portion of those not having been breastfed or presenting with signs of nutritional stress (cf. Beaumont et al., 2015).

The utilized method does not allow for determining whether the breastmilk consumed by the studied infant was provided by their biological mother, but the rarity of professional wet nurses in Finland (Lönnroth, 1981 [1838/1856]) makes it likely. Employing a wet nurse would reflect very different parental attitudes. Nevertheless, maternal mortality at the time was prevalent, and orphaned newborns could have been fostered by other nursing mothers.

Oulu parish was not mentioned as one of the worst regarding infant mortality, and analyzing a sample from another Ostrobothnian parish could yield different results. Nevertheless, there are suggestions of quite a remarkable problem in Oulu, as for instance according to an unofficial site for genealogists containing digitalized records (HisKi), in 1754–1763, 65% of those buried were children, although their ages were not marked. Moreover, in 1751, 25 of the 47 deceased were infants. Interestingly, of these, only five were boys (OMA IIdf:1, n.d.). Knowing this, the uncertainty in determining the sexes of the subjects is rather frustrating, although the division is not necessarily surprising given that Finnish society prior to the late 20th century was strongly patriarchal, and already as children, boys as heirs were much higher esteemed (Apo, 1995, pp. 203–209). This could have been a factor influencing breastfeeding customs.

6 | CONCLUSIONS

The mid-18th-century state officials of Sweden became concerned over mothers in early modern Ostrobothnia not breastfeeding and that artificial feeding was connected to the region's high infant mortality. The $\delta^{13}C$ and $\delta^{15}N$ values of the collagen of incrementally cut M1 crown dentin segments of six individuals excavated from the late 17th- to 18th-century churchyard of Oulu, Ostrobothnia, were analyzed to preliminarily explore local breastfeeding practices. The results suggest that they may have been quite varied. In the sample, one infant was likely not exclusively breastfed, and for half, the breastfeeding period was rather short at best. The results obtained from corresponding study from 19th-century Rauma, Southwestern Finland, generally indicated longer and more uniform breastfeeding periods. Based on the previous knowledge concerning regional diversity in breastfeeding customs, this was to be expected, as the mothers in Southwestern Finland have been presumed to have traditionally mainly resorted to breastfeeding.

Nevertheless, for some of the studied individuals, breastfeeding ended rather abruptly. The conviction of the elite was that the early modern common women of Ostrobothnia refused to breastfeed out of choice—even malevolence. Rather than that, however, the prevailing norms, regulations, and obligations shaped infant feeding practices, and the mothers did as had seemingly always been done. The necessity to participate in time-consuming and physically demanding work was a more pressing reason for a possible failure to breastfeed for sufficiently long periods. The results, however, do not directly support the previous understanding that Ostrobothnian mothers would have fed even the smallest infants with feeding horns and thus bring "archeological justice" for the caring mothers.

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CONFLICTS OF INTEREST

There was no conflict of interest.

DATA AVAILABILITY STATEMENT

The data used in this study will be uploaded to the *dIANA—Dietary Isotopic Baseline for the Ancient North* database available at https://www.oasisnorth.org/diana.html.

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